ESC201T : Introduction to Electronics

HW7: Solution

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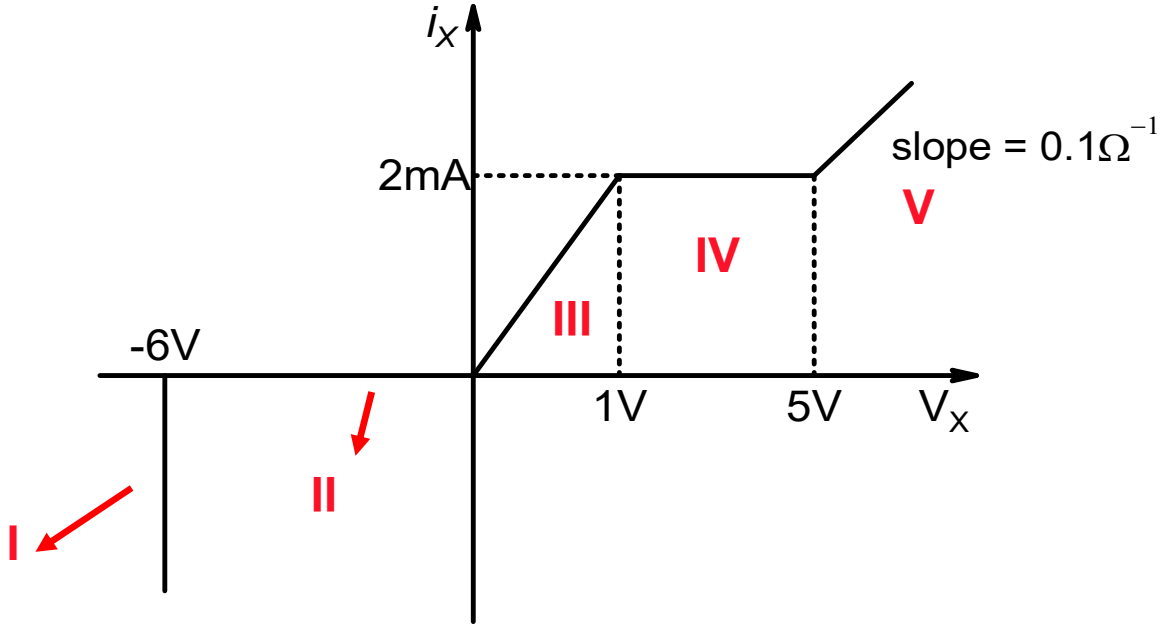
Q.1 Figure below shows current voltage characteristics of a two terminal device. One can note that there are five distinct regions of operation. Determine equivalent circuit for each of these regions in terms of common circuit elements such as resistors, voltage and current sources etc



Region -1: Voltage source of value -6V

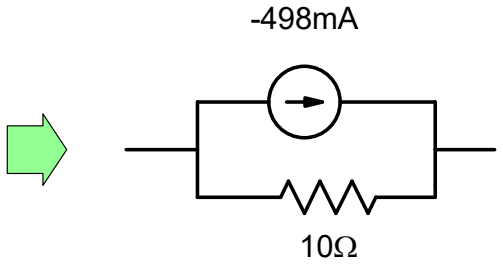
Region-2: open circuit

Region-3: resistor of value 1/2mA = 0.5K

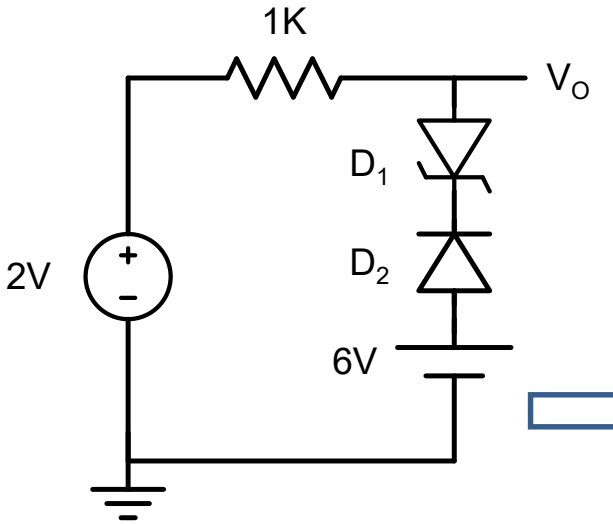
Region-4: Current source of 2mA

Region-5:

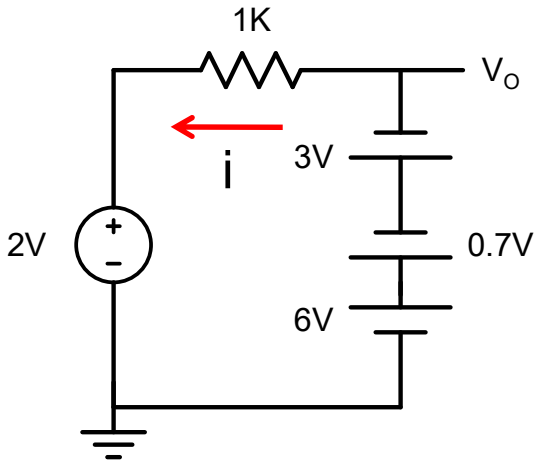
$$I_X = 2mA + 0.1 \times (V_X - 5)$$
$$= -498mA + \frac{V_X}{10}$$



Q.2 Determine the output voltage with reference to ground for the circuits shown below assuming that cut-in voltage of both diode and zener diode is 0.7V and that Zener voltage is 3V



Diode D2 is forward biased. Assume zener is like a 3V battery



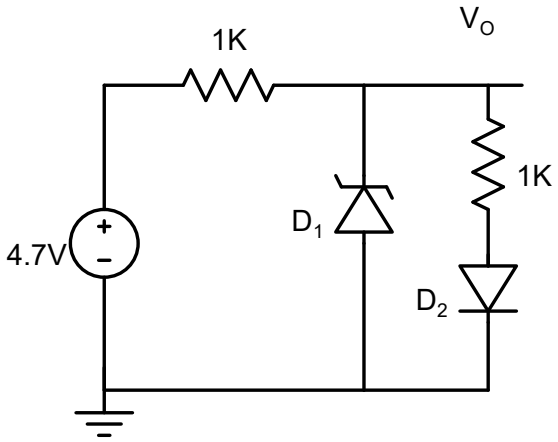
Let us calculate the current to check our assumption

$$-6 + 0.7 + 3 + i \times 10^3 + 2 = 0 \Rightarrow i = 0.3mA$$

Assumption is correct

$$-6 + 0.7 + 3 + v_o = 0 \Rightarrow v_o = 2.3V$$

b.



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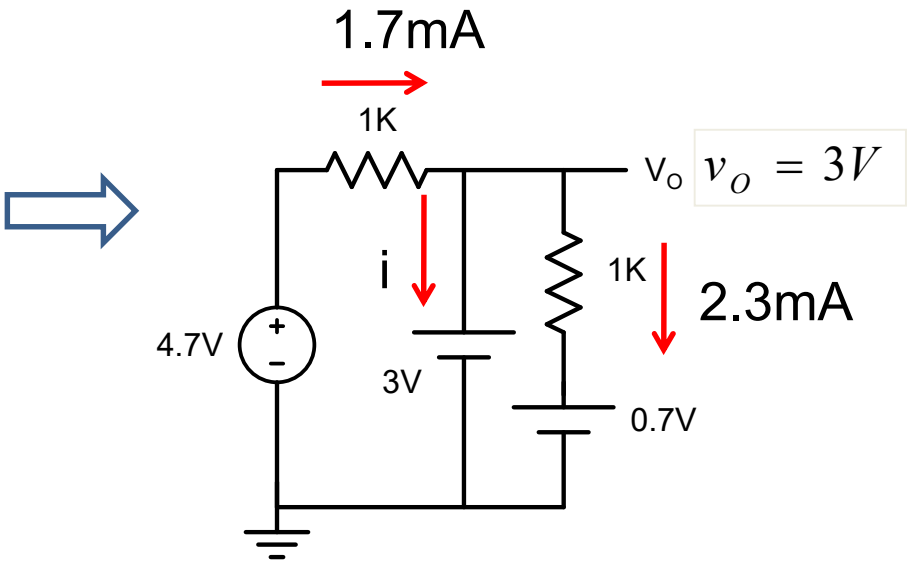
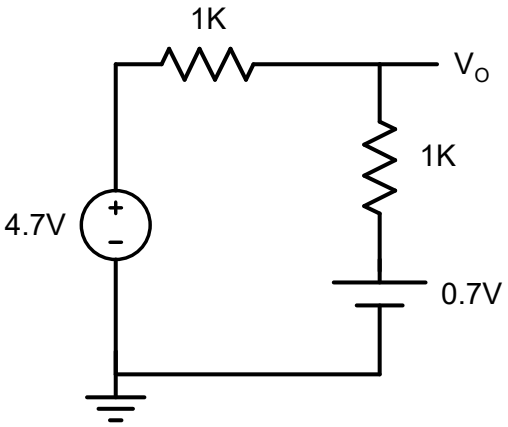


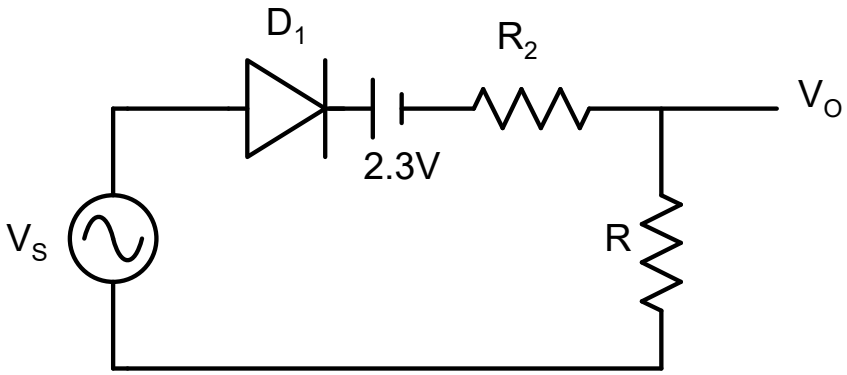
Let us calculate the zener current to check our assumption

I = -0.6mA so assumption is incorrect and zener is like an open circuit



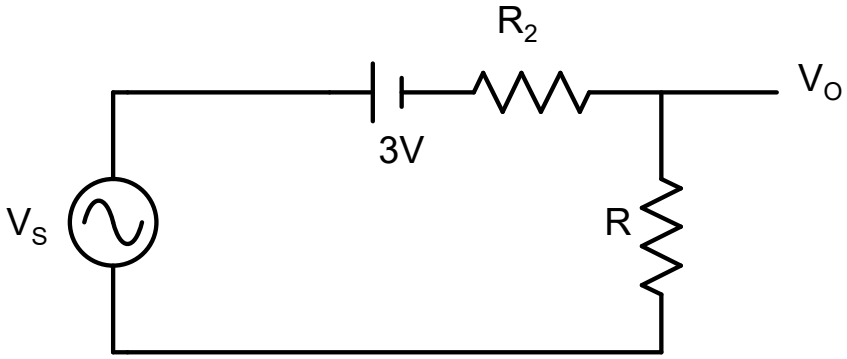
$v_O = 2.7V$

Q.3 Sketch the output voltage vs. input voltage characteristics for the clipper circuit shown below assuming cut-in voltage of both diode and zener diode is 0.7V and that Zener voltage is 3V

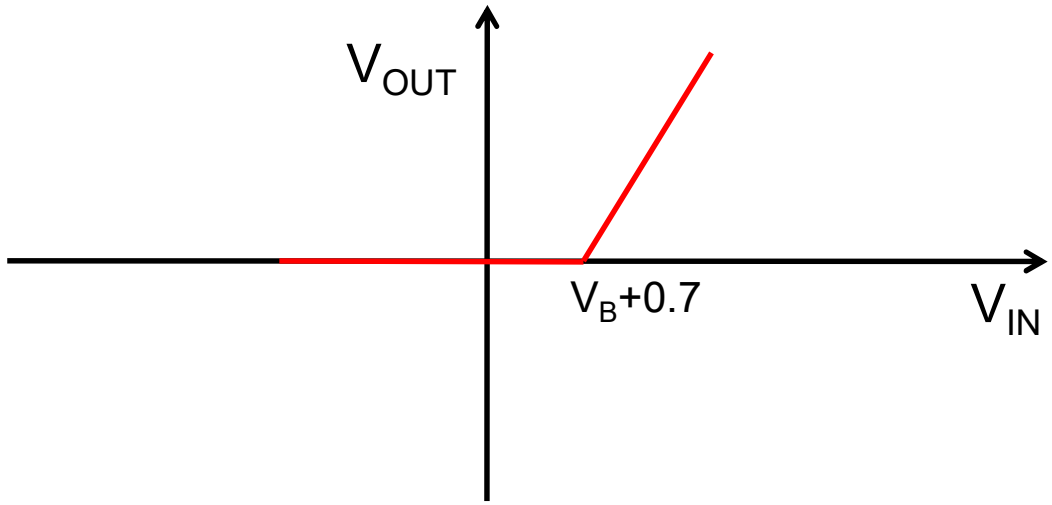


For negative cycle diode is reverse biased So there is no current in the circuit and Vo = 0.

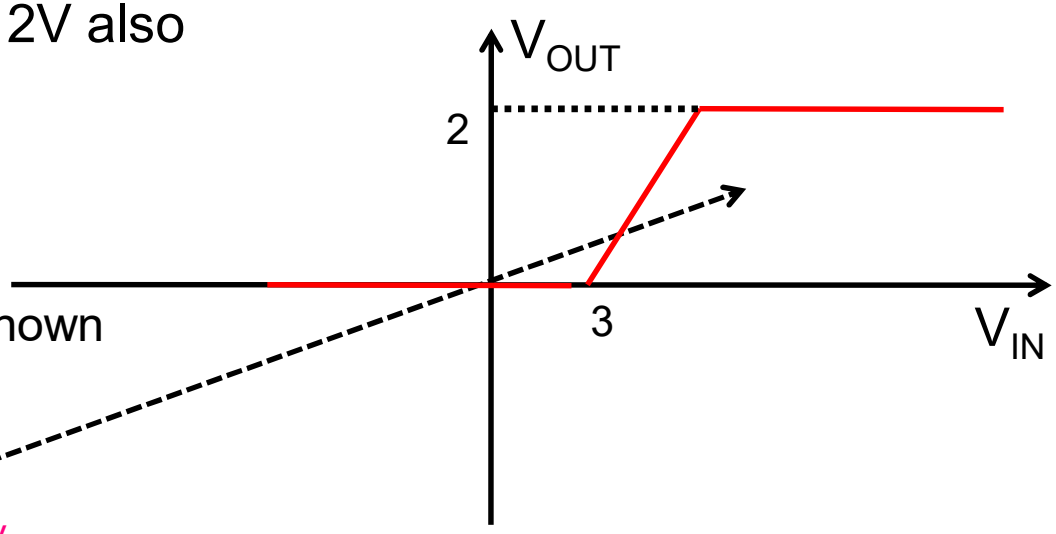
For positive cycle, diode will remain reverse biased till input voltage crosses 0.7+2.3= 3V. Once that happens the circuit becomes



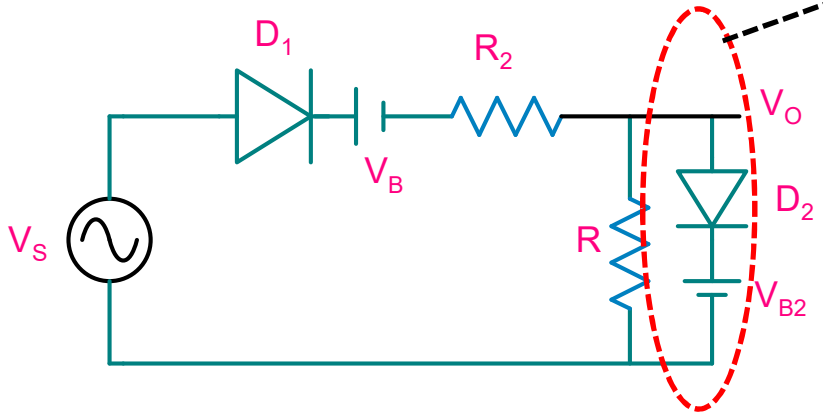
$$v_O = (V_S - 3) \times \frac{R}{R + R_2}$$



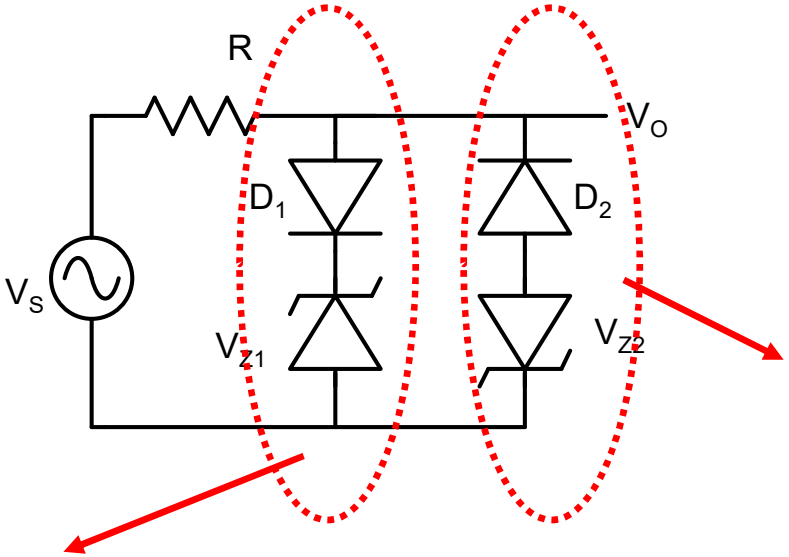
If we have to clip the voltage at 2V also



We can add a diode with a battery as shown

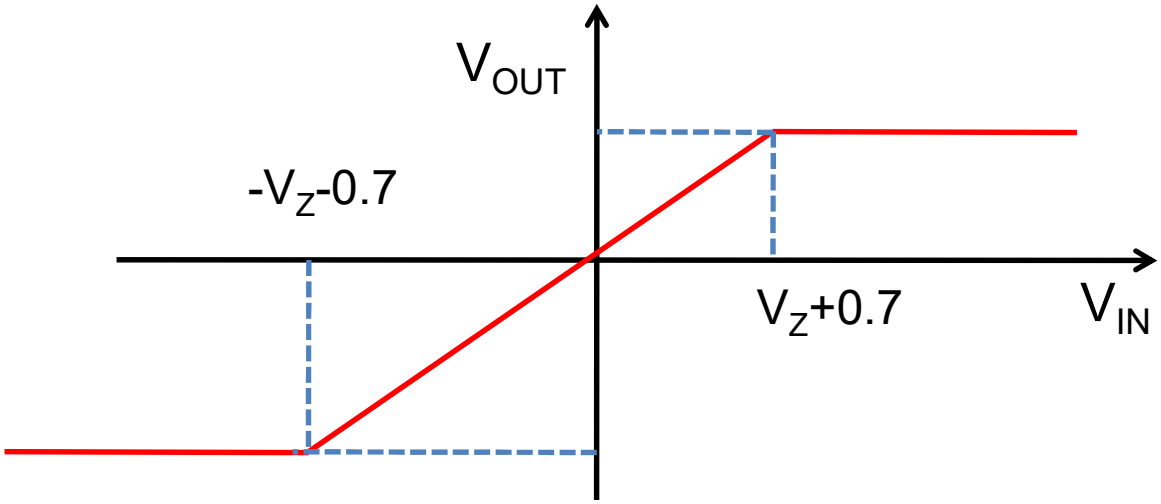


$$V_{B2} = 2 - 0.7 = 1.3V$$

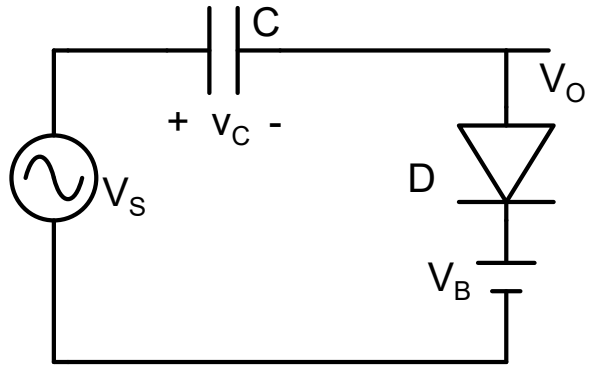


This will turn ON when input voltage exceeds $-V_Z$-0.7. Once this happens the output is fixed to this value

This will turn ON when input voltage exceeds V_Z+0.7. Once this happens the output is fixed to this value



Q.4 Sketch the output voltage for the clamper circuit shown below for sinusoidal input and assuming ideal diode



As long as the diode is conducting the capacitor will charge till maximum capacitor voltage is reached. Beyond that capacitor voltage will remain constant because diode will be reverse biased and there is no path for the capacitor to discharge.

If the maximum value of input voltage is V_M

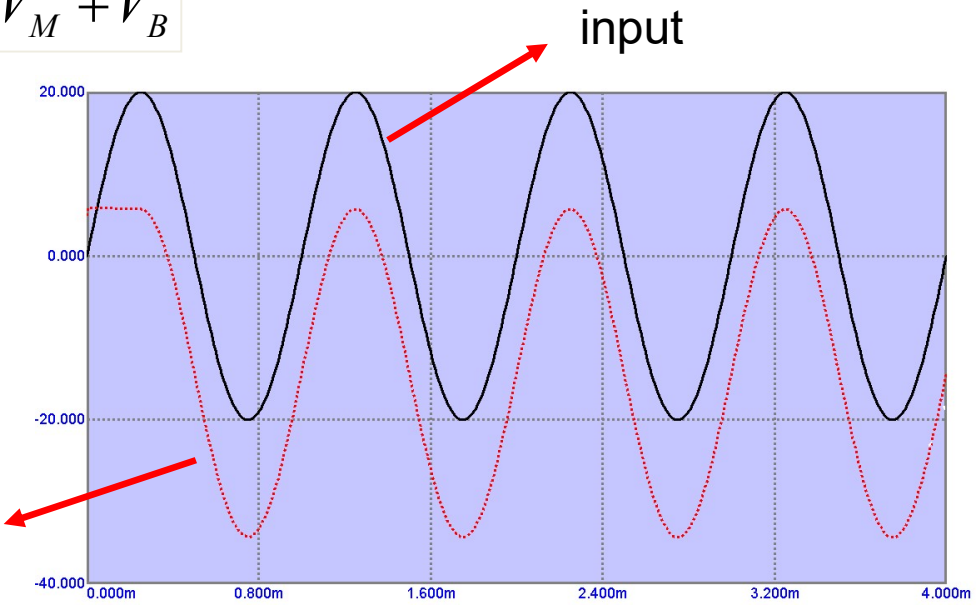
$$v_C(\max.) = V_M - V_B$$

Since diode is reverse biased and there is no current in the circuit

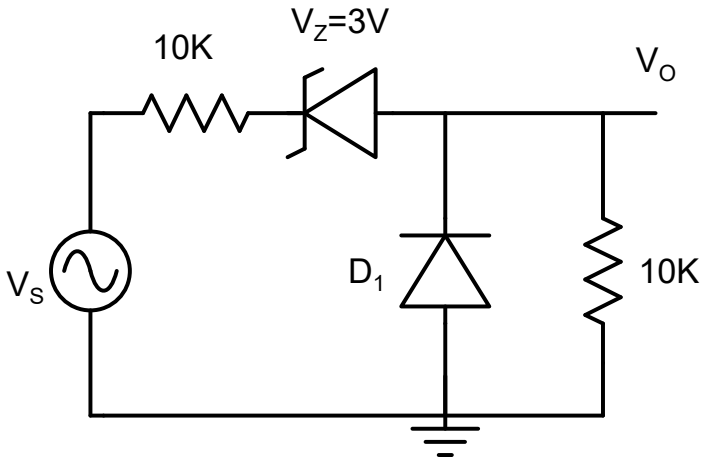
$$v_O(t) = V_S - v_C(\max.) = V_M Sin(\omega t) - V_M + V_B$$

The input is shifted down by an amount

$$V_M - V_B$$

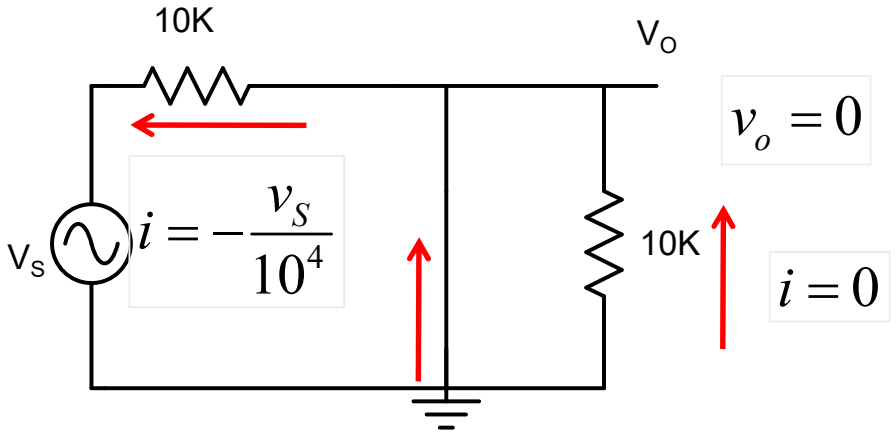


Q.5 Determine the input-output characteristics of the circuit shown below for input voltage varying between -10 and 10 V. assume that cut-in voltage of the diodes is zero.



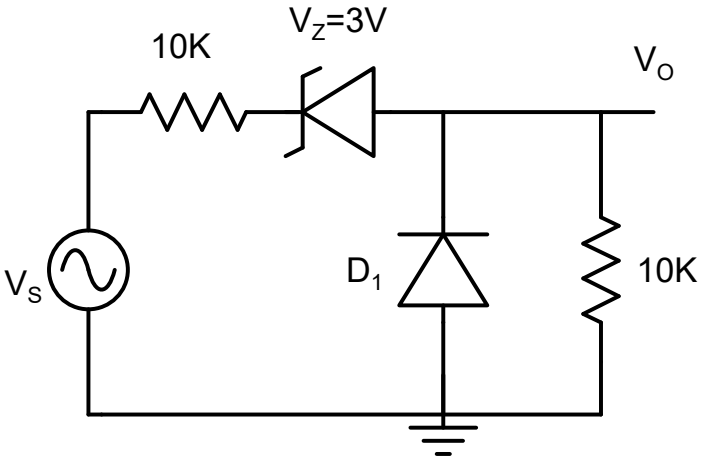
When vi is negative zener diode is forward biased.

Let us assume that D1 is also forward biased and find out the appropriate condition for this to occur

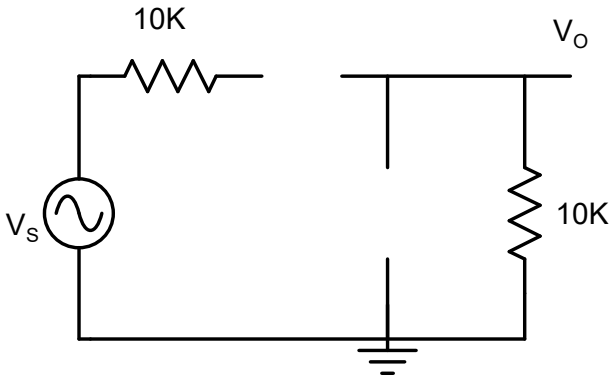


So diode is forward biased as current through it is in right direction

So for negative vs, output is zero

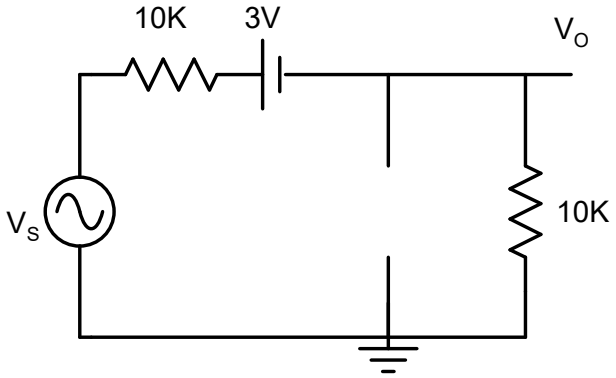


For positive vs, zener is reverse biased and carries zero current until the voltage reaches zener breakdown voltage of 3V. Diode D1 is also reverse biased

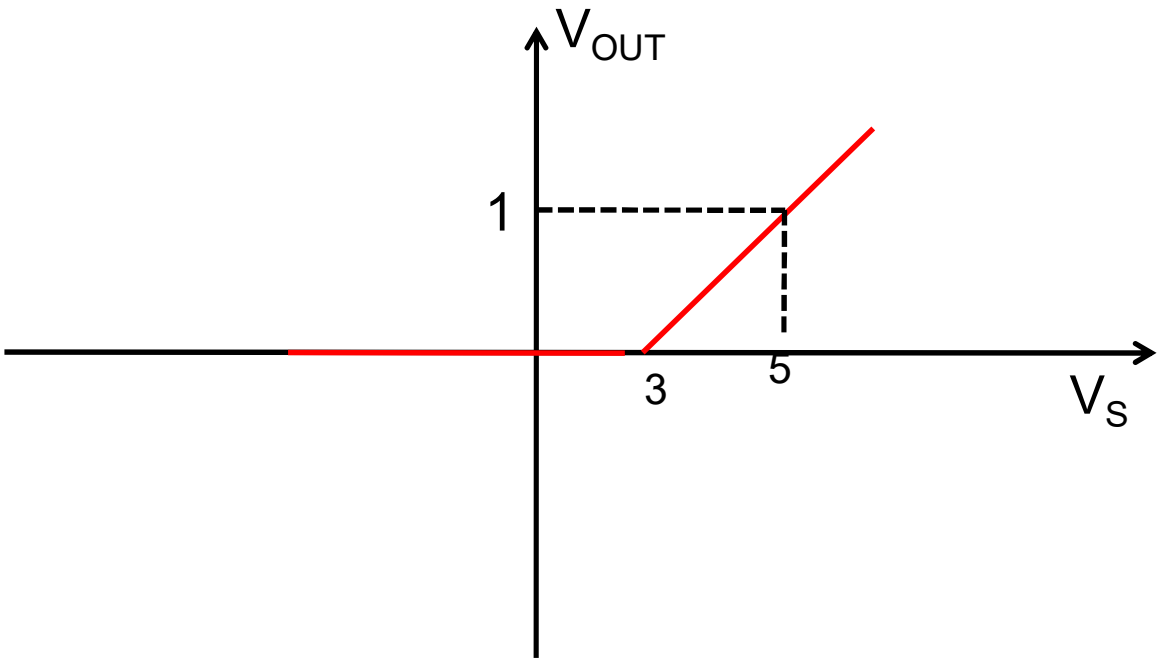


$$v_o = 0$$

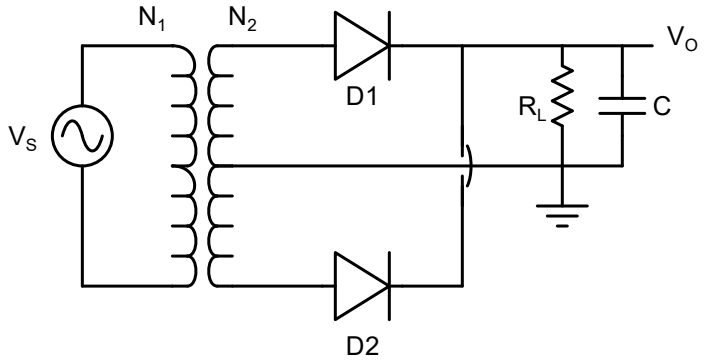
Once the voltage exceeds 3V, zener can be replaced by 3V battery and equivalent circuit becomes



$$v_o = (v_S - 3) \times \frac{10}{10+10} = 0.5v_S - 1.5V$$


V_{OUT}
1
3
5
V_S

Q.6 Design the power supply circuit shown above on the right that will supply 10V to a load of 1000Ω with ripple voltage less than 0.2V. As part of the design , determine transformer turns ratio, value of capacitance , diode peak current and peak inverse voltage. Assume that input is 220V rms with a frequency of 50Hz



For V_O to be 10V, the input V_{IN} should be ~ 2 x 10.7 = V

$$\frac{N_1}{N_2}=\frac{311.127}{21.4}=14.53$$

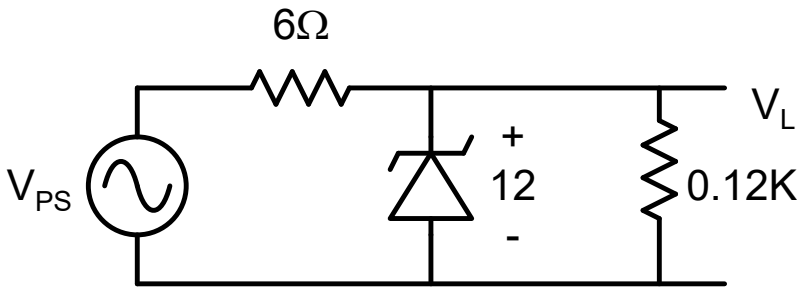
$$V_r \cong \frac{V_M}{2fR_LC} \Rightarrow C = 0.5mF$$

$$i_{D\max} \cong \omega C \times \sqrt{2V_rV_M} + \frac{V_M}{2R_L} = 0.319A$$

$$i_D^{av} \cong \frac{V_M}{2R_L} = 5mA$$

$$PIV \cong 2v_O + 0.7 = 20.7V$$

Q.7 For the circuit shown below, can a Zener diode with a maximum current rating of 0.25A be used? The input voltage varies between 13 and 15V



In this case load current is fixed so

$$I_{L\max} = I_{L\min} = \frac{V_Z}{R_L} = 0.1A$$

$$I_{Z\max} = \frac{V_{PS\max} - V_Z}{R_i} - I_{L\min} = 0.4A$$

Since max. zener current is larger than the current rating so it would not be possible to use the given zener diode.